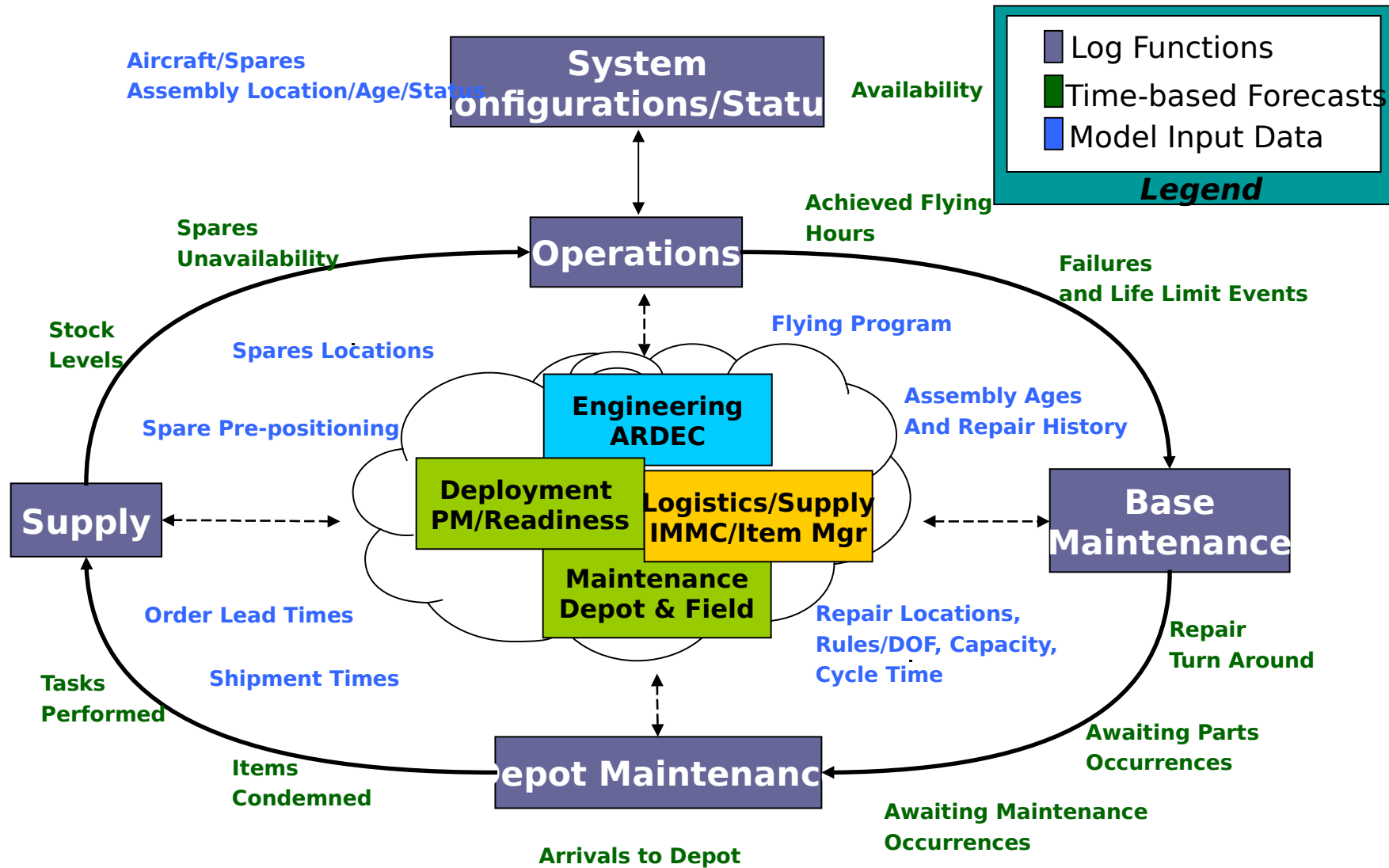


ATLAST Deployment & Push Pack Spares Optimizer

Presented by
Dr. Naaman Gurvitz

ATLAST Model Logic



ATLAST Strengths & Applications

■ Real-World Complexities (State-based Forecasting)

- Supports Initialization Down to Serial Number
- Initialized “State” of Components
- Phased Aircraft Inductions by Tail Number
- Aging Analysis
- Recap, Zero Aging Analysis
- Distribution Swapping based on Repair Count
- Reconfigurable Indenture Structures
- Life Limit Event Management
- Op Temp Variations by Location
- Interchangeability/Substitutability

■ Analysis to be Supported with Model

- Maintenance Concept Modifications (e.g. Recapitalization)
- Aircraft Induction Strategies
- Operations Surge
- Parts Purging
- Sparing Strategies
- Deployment Planning

ility

Capacity Constraints

Time-Dependent Outputs

ATLAST Deployment & Push Pack Spares Optimizer

ATLAST Outputs

■ Readiness

- Time on Wing
- Availability
- Achieved Flying Hours
- Cumulative Age

■ Supply

- % of Time Awaiting Parts
- Avg. Time Awaiting Parts
- Spares Stock Levels
- Spares Unavailability

■ Maintenance

- Removals
(Causal, Timed, Opportunistic)
- Modules to Depot
- Condemnations
- Tasks Performed
- % of Time Awaiting Maintenance
- Avg. Time Awaiting Maintenance

■ Cost

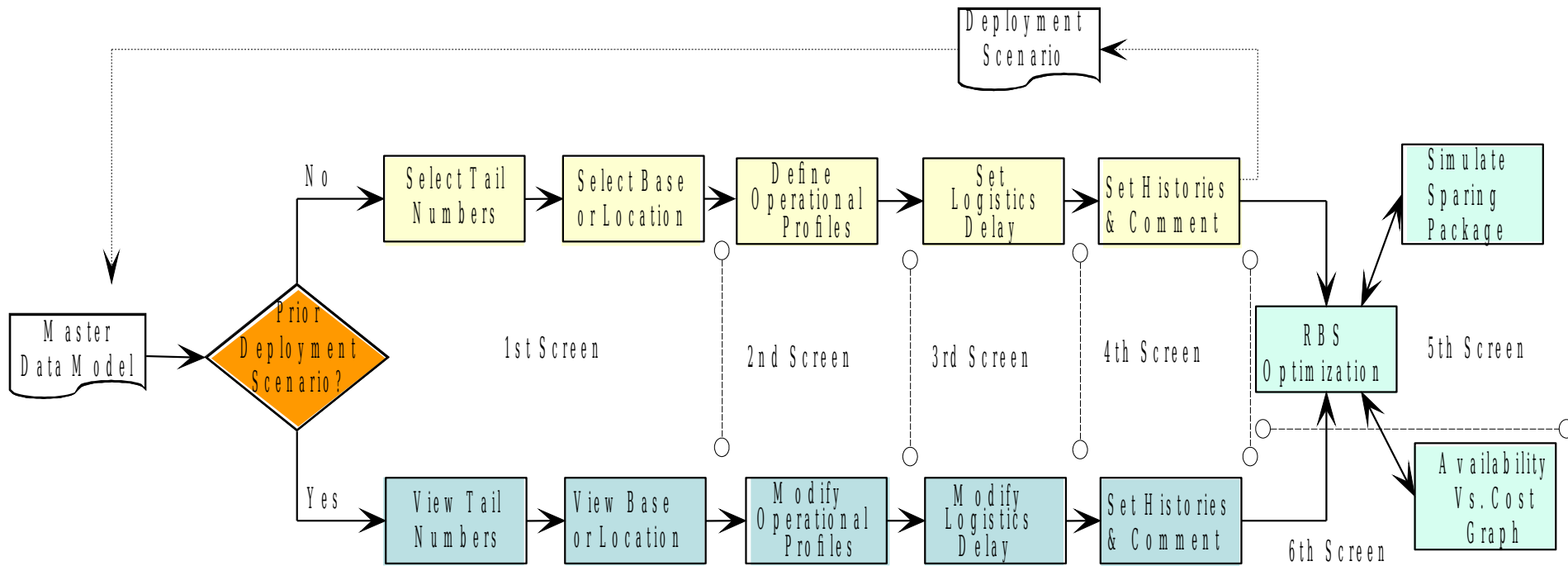
- O&S
- O&S Per Flight Hour

By Location and Time Dependent

ATLAST Optimizer

- Deployment & Push Pack Spares Optimization Module:
 - Creates a full deployment scenario on any number of aircraft at a single base
 - User defines logistics delay and operational profiles
 - Generates availability vs. cost graph
 - Provides analyst necessary information to determine optimal spares pack

Scenario Setup Process



Scenario From Master Database

AT-LAST
Aircraft Total Life-Cycle Assessment Software Tool

Deployment and Push Pack Spares

Clockwork Solutions

Select Master database for Deployment scenario
C:\ATLAST\Databases\UAV Demo\Set 3 Optimized IP\3-1 UAV demo (ver4) Baseline.mdb

Set Deployment scenario database
C:\ATLAST\Databases\UAV Demo\Set 3 Optimized IP\3-2a UAV demo (ver4) Base 1 IP.mdb

OR

Select Base for Deployment
Select the base: BASE 1 OPS Change the Base name: BASE 1 OPS

Select # deployed aircraft

Tail No	MDS	Base From	Include?
000001	UAV	BASE 1 OPS	☒
000002	UAV	BASE 1 OPS	☒
000003	UAV	BASE 1 OPS	☒
1000004	UAV	BASE 1 OPS	☒
1000005	UAV	BASE 1 OPS	☒
2000001	UAV	BASE 2 OPS	☒
2000002	UAV	BASE 2 OPS	☐
2000003	UAV	BASE 2 OPS	☐
3000001	GROUND	GROUND OPS	☐

Restart Optimizer **Return** **Previous** **Next**

Callouts:

- Select Master Database
- Choose Deployment Scenario name
- Select Base
- Type Location
- Select aircraft tail numbers

Scenario From Master Database

AT-LAST Deployment and Push Pack Spares

AT-LAST
Aircraft Total Life-Cycle Assessment Software Tool

Clockwork Solutions

Select Master database for Deployment scenario
C:\ATLAST\Databases\UAV Demo\Set 3 Optimized IP\3-2a UAV demo (ver4) Base 1 IP.mdb

Set Deployment scenario database
C:\ATLAST\Databases\UAV Demo\Set 3 Optimized IP\3-2a UAV demo (ver4) Base 1 IP.mdb

New Deployment Scenario
View Deployment Base
View Deployed Aircraft
Set Flight Hours Program
Set Logistics Delay Time
Set Simulation Parameters
Optimization Control Panel

Set the quarterly flying rate for the aircraft
Duration of the Deployment Scenario 8 quarters

Aircraft at Base	Year	Qtr	Distribution	Mean	SD (%)
UAV	2003	4	Constant	200.00	0.00
UAV	2004	1	Constant	200.00	0.00
UAV	2004	2	Constant	200.00	0.00
UAV	2004	3	Constant	200.00	0.00
UAV	2004	4	Constant	200.00	0.00
UAV				200.00	0.00
UAV				200.00	0.00
UAV				200.00	0.00

Define Deployment Period

Retrieve original flying rate

Change Flying rate

☐ Distribution
☐ Mean
☐ Standard Deviation

Set

Restart Optimizer

Return

Previous

Next

Assign Operational Profile

Scenario From Master Database

AT-LAST
Deployment and Push Pack Spares

AT-LAST
Aircraft Total Life-Cycle Assessment Software Tool

Clockwork Solutions

Select Master database for Deployment scenario
C:\ATLAST\Databases\UAV Demo\Set 3 Optimized IP\3-2a UAV demo (ver4) Base 1 IP.mdb Browse

Set Deployment scenario database
C:\ATLAST\Databases\UAV Demo\Set 3 Optimized IP\3-2a UAV demo (ver4) Base 1 IP.mdb Save As

New Deployment Scenario

- View Deployment Base
- View Deployed Aircraft
- Set Flight Hours Program
- Set Logistics Delay Time**
- Set Simulation Parameters
- Optimization Control Panel

Set Logistical Time Delay for each WUC

WUC Name	Distribution	Mean	SD (%)
FLIGHT CONTROL	Constant	48.46	0.00
FUEL SYSTEM	Constant	30.69	0.00
INFRA-RED SENSOR	Constant	51.40	0.00
NAVIGATION CONTROL	Constant	59.00	0.00
OPTICAL SENSOR CONTROL	Constant	44.88	0.00
PROPULSION	Constant	29.04	0.00
RADA	Constant	46.73	0.00
SATC	Constant	59.00	0.00
WING-PORT	Constant	23.56	0.00
WING-STBD	Constant	22.91	0.00

Set Logistic Delays

Retrieve original Time Delay

Change Flying rate

☐ Distribution

☐ Mean

☐ Standard Deviation

Set

Restart Optimizer

Return

Previous

Next

Scenario From Master Database

The screenshot shows the AT-LAST software interface with the following elements:

- Window Title:** AT-LAST Deployment and Push Pack Spares
- Logo:** AT-LAST Aircraft Total Life-Cycle Assessment Software Tool
- Navigation Menu (Left):**
 - New Deployment Scenario
 - View Deployment Base
 - View Deployed Aircraft
 - Set Flight Hours Program
 - Set Logistics Delay Time
 - Set Simulation Parameters
 - Optimization Control Panel
- Buttons (Top Right):** Browse, Save As
- Form Fields:**
 - Select Master database for Deployment scenario:** C:\ATLAST\Databases\UAV Demo\Set 3 Optimized IP\3-2a UAV demo (ver4) IP.mdb
 - Set Deployment scenario database:** C:\ATLAST\Databases\UAV Demo\Set 3 Optimized IP\3-2a UAV demo (ver4) IP.mdb
 - Number of histories:** 100 (dropdown menu)
 - Start Date:** November 1, 2002
 - Compact database after run:** ☒
 - Name:** John
 - Department:** Clockwork
 - Graph Label:** Base 1 IP
 - Description:** As model 3-2, Base 1 IP calculation
- Buttons (Bottom):** Restart Optimizer, Return, Previous, Next

Two yellow callout boxes highlight specific features:

- Set Number of Histories:** Points to the 'Number of histories' dropdown menu.
- Type Descriptive Information:** Points to the 'Name', 'Department', 'Graph Label', and 'Description' fields.

Simulation & Optimization

AT-LAST
Aircraft Total Life-Cycle Assessment Software Tool

Deployment and Push Pack Spares

Select Master database for Deployment scenario

Optimized IP\3-2a UAV demo (ver4) Base 1 IP.mdb

Optimized IP\3-2a UAV demo (ver4) Base 1 IP.mdb

Browse

Save As

Run Simulation Verifications

Select Ranking Method

View spare parts ranking by

Effectiveness (%) Cost Effectiveness (%/\$)

View Deployment Scenario

View Deployment Base

View Deployed Aircraft

Set Flight Hours Program

Set Logistics Delay Time

Ranked Spares List associated with Cost and Estimated Performance

Rank	WUC of Spare	Total Cost \$	Estimated Availability (%)	Simulated Availability (%)
0		0.00	57.98028	0.00000
1	FUEL SYSTEM	10,000.00	63.15694	0.00000
2	CONTROL	20,000.00	66.86966	0.00000
3		30,000.00	70.34373	0.00000
4	PROPULSION	40,000.00	73.86383	0.00000
5	FLIGHT CONTROL	50,000.00	77.21221	0.00000
6	FUEL SYSTEM	60,000.00	80.61827	0.00000
7	INFRA-RED SENSOR	70,000.00	84.13144	0.00000
8	OPTICAL SENSOR CONTROL	80,000.00	87.43665	0.00000
9	SATCOM	90,000.00	89.60498	0.00000
10	NAVIGATION CONTROL	100,000.00	91.33553	0.00000

Previous

Next

Sparring Strategy

Simulate

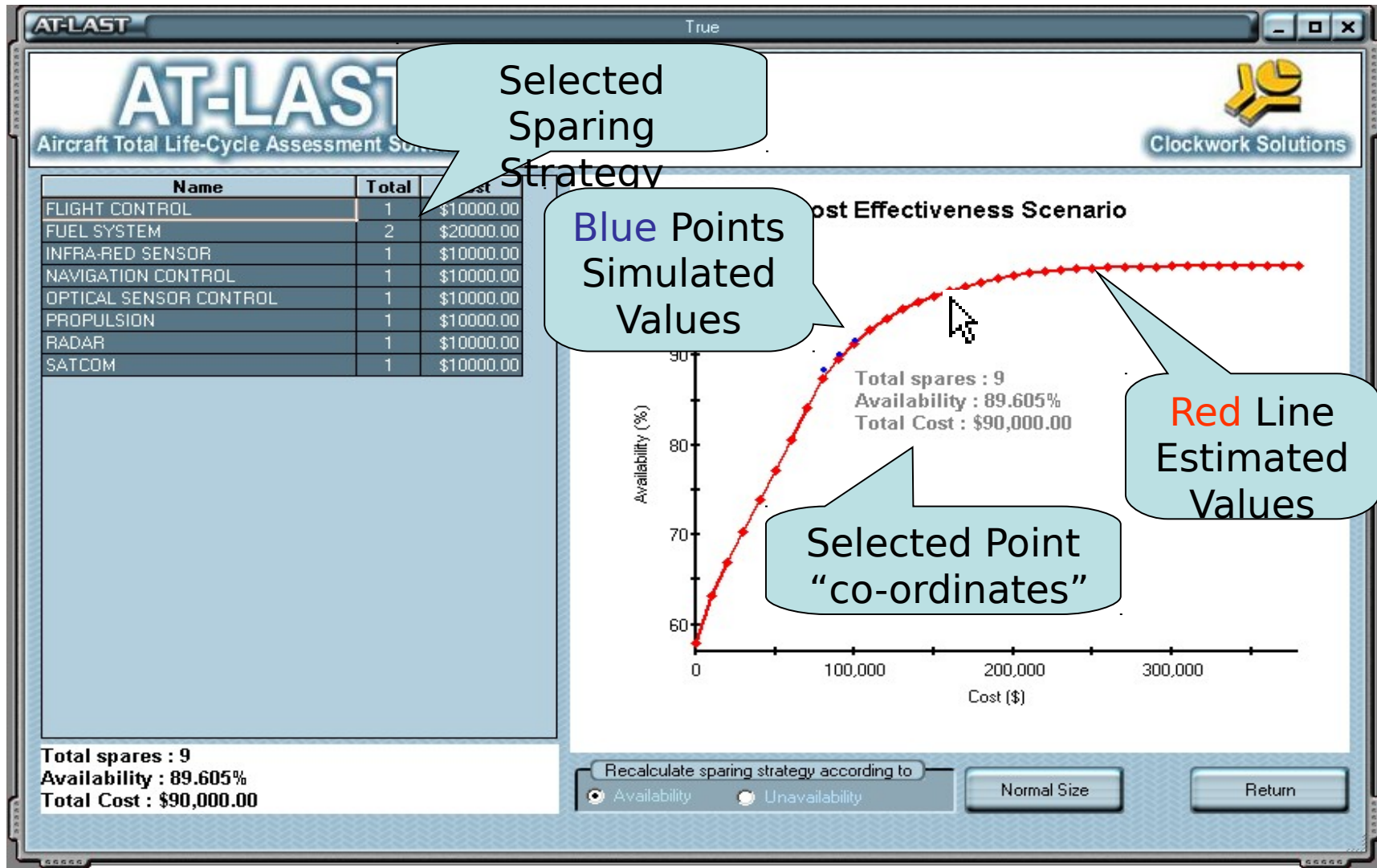
Save

View results

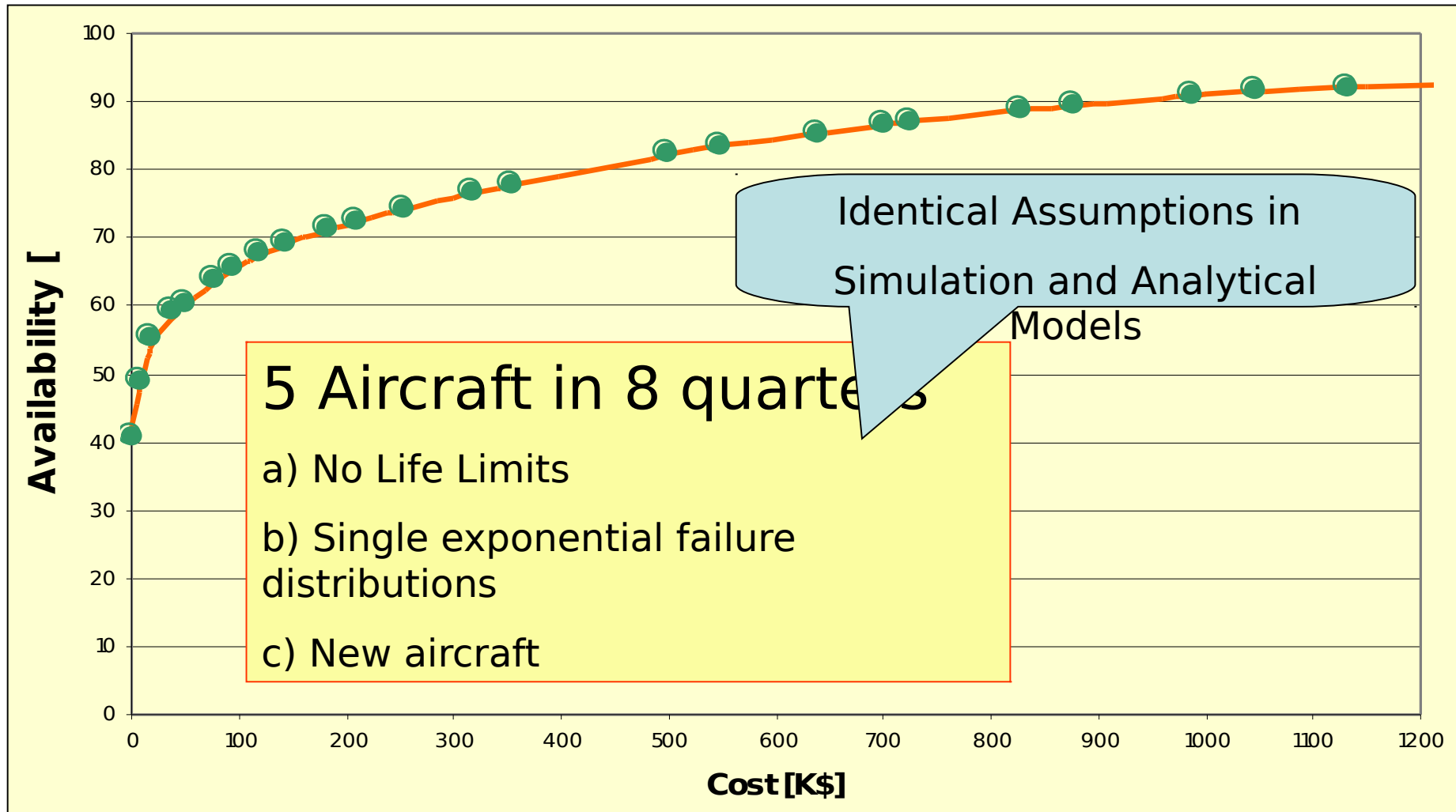
Select Sparring Strategy and Run Simulation Verification

Autorun simulations

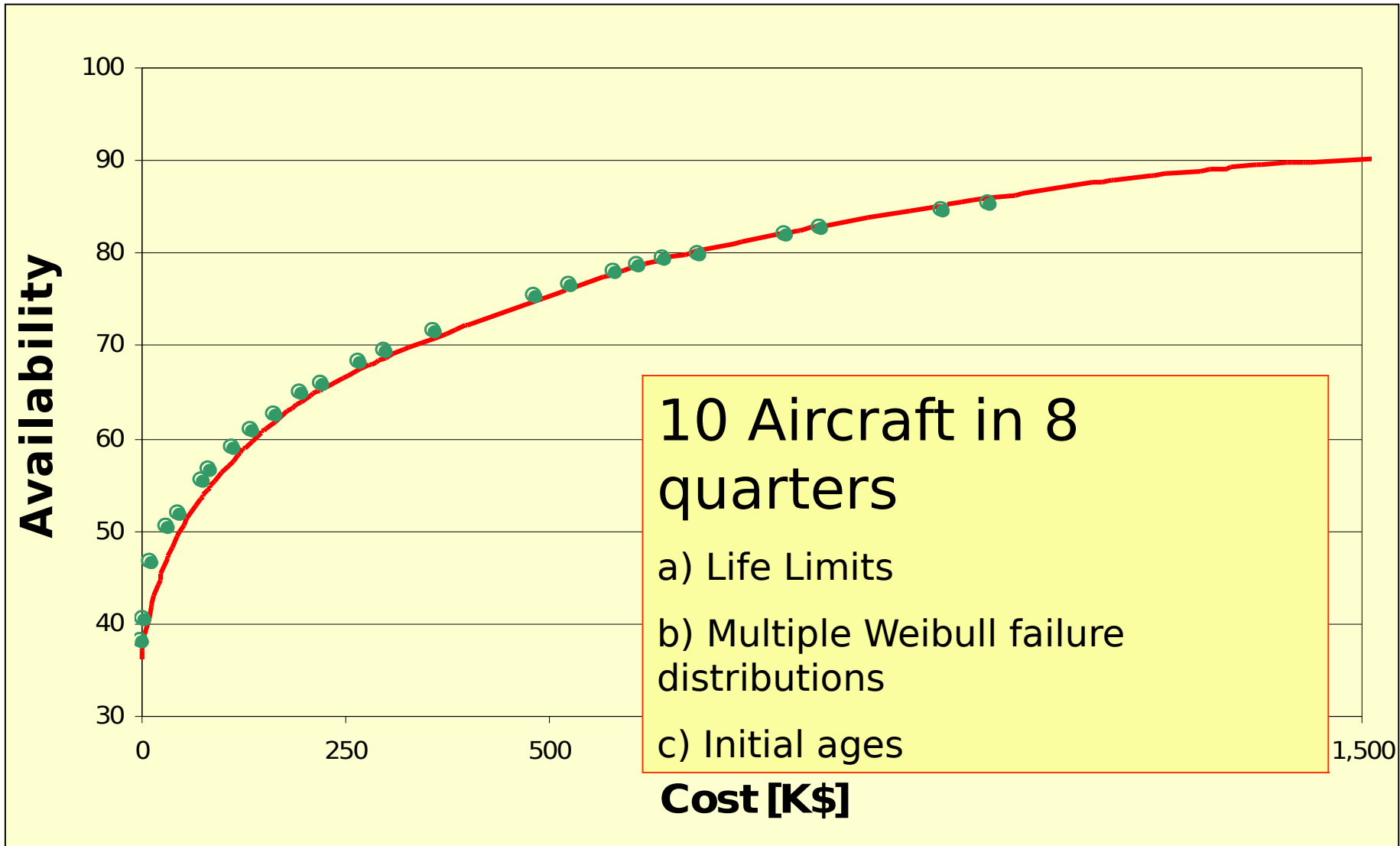
Simulation & Optimization



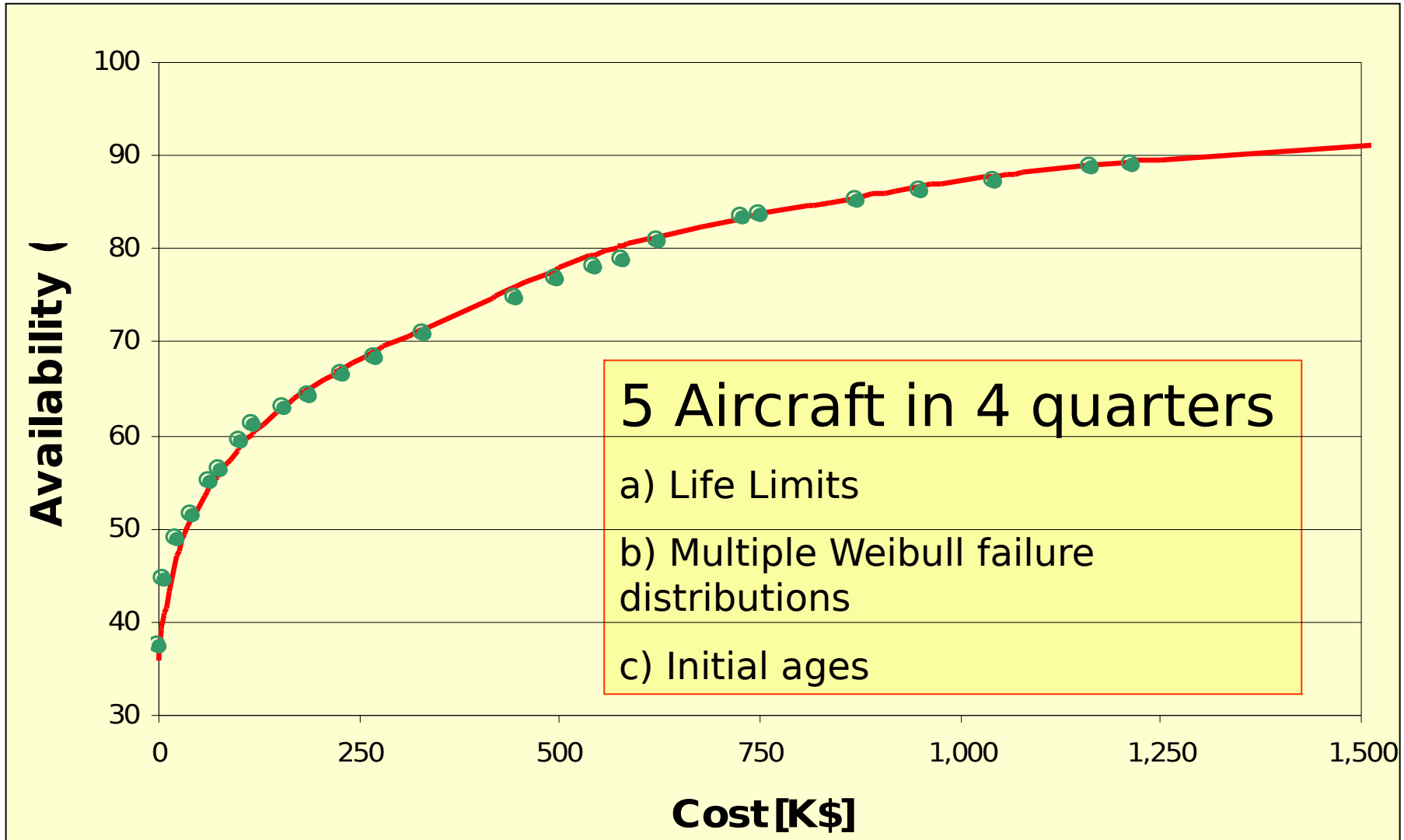
Validation



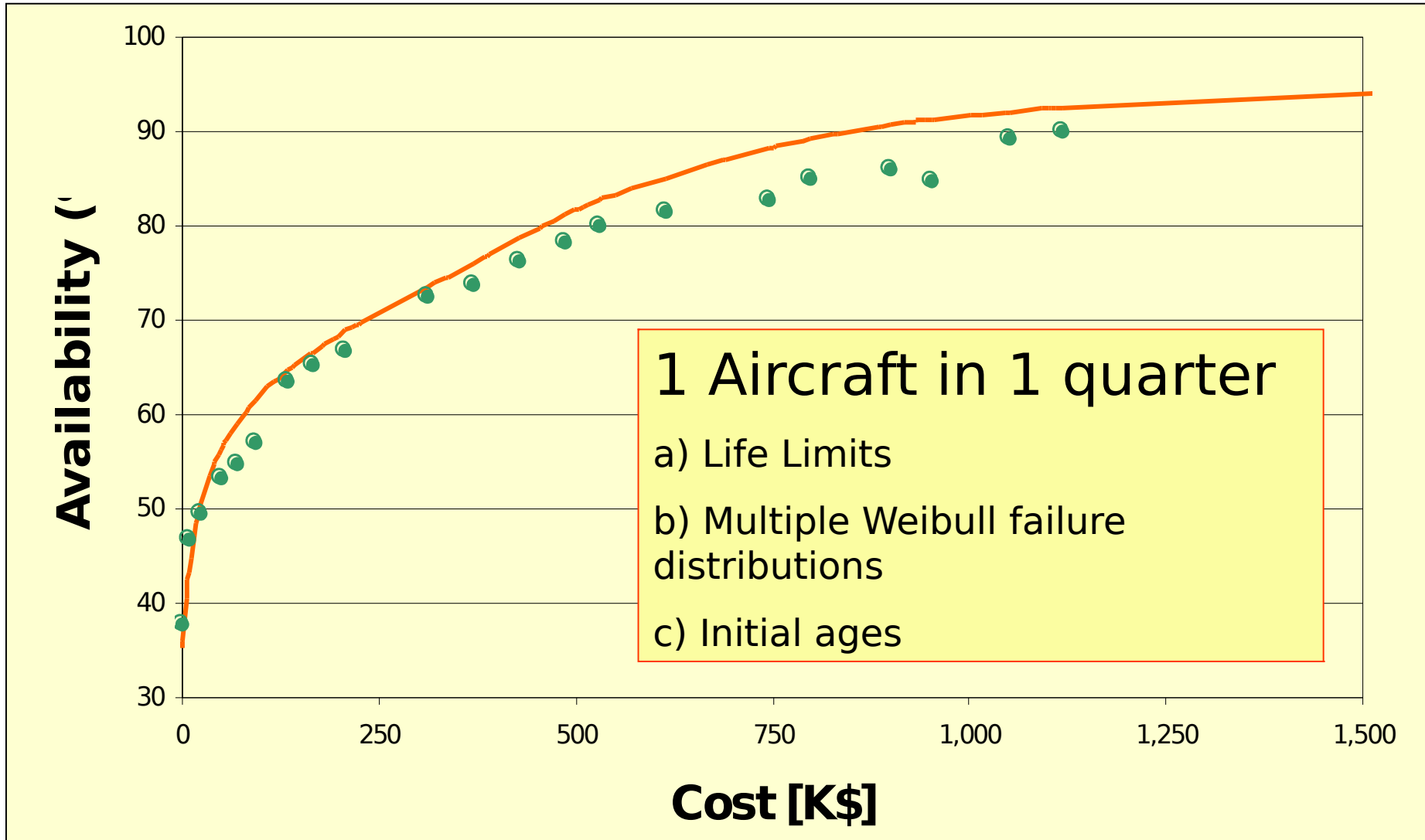
Numerical Results: Case A



Numerical Results: Case B



Numerical Results: Case C



Conclusions

- AT LAST Deployment Push Pack Spares Optimization Module is both **accurate** and **efficient**
- Further developments will include:
 - An automatic adjustment mechanism
 - Improved handling of “coinciding” LRU removals occurrences
 - Importing optimization results to the master database



Thank You

Backup Slides

Mathematical Formulation

Markov Process States

Legen

n =number of systems

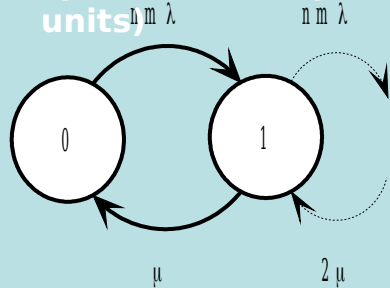
m =number of LRU's per system

s = number of spares

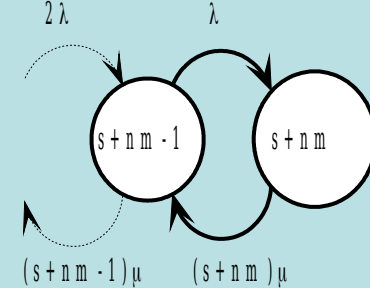
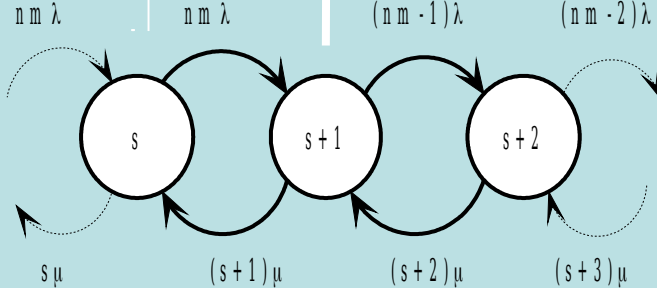
λ = effective failure rate

μ = repair turnaround rate

Same failure rates (enough spares to 'fill up' for failed units)



Reducing failure rates (function of operational units)

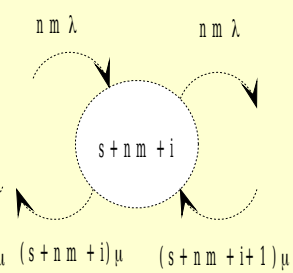
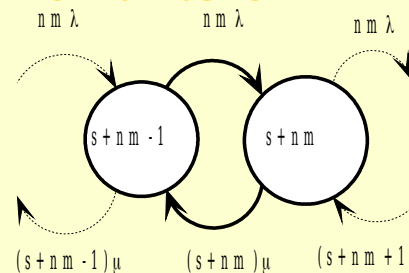
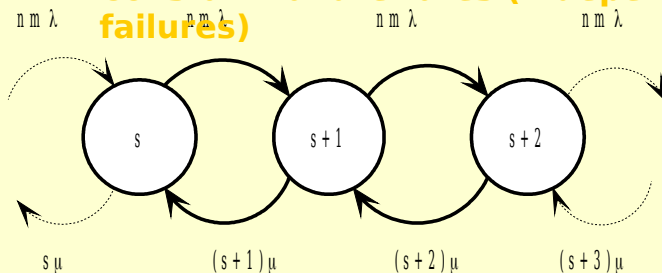
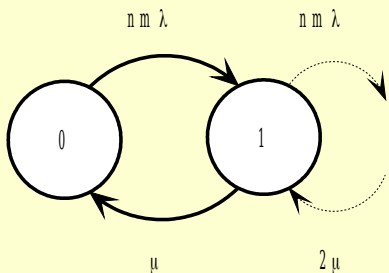


Repair rates function of number of failed units

AT-LAST - Finite Markov State

Process

Constant failure rates (independent of number of failures)



Repair rates function of number of failed units

Traditional - Infinite Markov State

Steady State Markov Equations

State 0	$0 = \mu P_1 - nm\lambda P_0$
	$\vdots$
State s	$0 = nm\lambda P_{s-1} + (s+1)\mu P_{s+1} - nm\lambda P_s - s\mu P_s$
State s+1	$0 = nm\lambda P_s + (s+2)\mu P_{s+2} - (nm-1)\lambda P_{s+1} - (s+1)\mu P_{s+1}$
	$\vdots$
State s+n·m	$0 = \lambda P_{s+nm+1} - (s+nm)\mu P_{s+nm}$
Boundary Condition	$\sum_{i=0}^{s+nm} P_i = 1$

State 0	$0 = \mu P_1 - nm\lambda P_0$
	$\vdots$
State s	$0 = nm\lambda P_{s-1} + (s+1)\mu P_{s+1} - nm\lambda P_s - s\mu P_s$
	$\vdots$
State s+n·m	$0 = nm\lambda P_{s+nm+1} + (s+nm+1)\mu P_{s+nm+1} - nm\lambda P_{s+nm} - (s+nm)\mu P_{s+nm}$
	$\vdots$
Boundary Condition	$\sum_{i=0}^{\infty} P_i = 1$

Steady State Probabilities

$$P_i = \begin{cases} \frac{(nm)^i}{i!} \left(\frac{\lambda}{\mu}\right)^i P_0 & \text{if } 1 \leq i \leq s \\ \frac{(nm)^s}{s!} \left(\frac{\lambda}{\mu}\right)^s \frac{(nm)^{i-s}}{(nm+s-i)!} P_0 & \text{if } s \leq i \leq s+nm \\ 1 + \sum_{i=1}^s \frac{(nm)^i}{i!} \left(\frac{\lambda}{\mu}\right)^i + \frac{(nm)^s}{s!} \left(\frac{\lambda}{\mu}\right)^s \sum_{i=s+1}^{s+nm} \frac{(nm)^{i-s}}{(nm+s-i)!} \left(\frac{\lambda}{\mu}\right)^{i-s} - 1 & \text{if } i > s+nm \end{cases}$$

$$P_i = \frac{(nm)^i}{i!} \left(\frac{\lambda}{\mu}\right)^i P_0 \quad \text{if } 1 \leq i < \infty$$

$$P_0 = e^{-\frac{\lambda}{\mu}}$$

**Poisson
Distribution**

Little Theorem $\lambda_{\infty} W = H$

$$W(s) = \frac{\frac{nm^s}{s!} (\lambda T)^s \cdot \sum_{i=s+1}^{s+nm} (i-s) \cdot \frac{nm!s!}{(nm+s-i)!i!} (\lambda T)^{i-s}}{\lambda \left[\sum_{i=0}^s \frac{nm^{i+1}}{i!} (\lambda T)^i + \frac{nm^s}{s!} (\lambda T)^s \cdot \sum_{i=s+1}^{s+nm-1} \frac{nm!s!}{(nm+s-i-1)!i!} (\lambda T)^{i-s} \right]}$$

Where: $T = \frac{1}{\mu}$ $\lambda = \frac{1}{MTTF + MTTR}$

$$W(s) = \frac{\sum_{i=s+1}^{\infty} (i-s) \cdot \frac{(nm\lambda T)^i e^{-nm\lambda T}}{i!}}{nm\lambda}$$

Where: $T = \frac{1}{\mu}$

Unavailability Estimates

ATLAST Expression: Applicable for serial systems in which LRU's do not fail while the system is down

$$U_{\text{sys}}(s_1, \dots, s_L) = 1 - \frac{1}{1 + \sum_{i=1}^L m_i \lambda_i (MTTR_i + W_i(s_i))}$$

Where $\lambda_i = \frac{1}{MTTF_i}$ **calculated from outputs**
e: